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INTRODUCTION

This is the ninth progress report on Research and Development Task 4. This month's report covers work done on a pulse duration modulated system that functions in a manner to provide security against detection by conventional receivers.

Previous progress reports have discussed the various advantages of pulse communications over conventional A.M. - F.M. systems. However, it was noted that a conventional receiver could detect the pulsed signal, on condition that a strong signal was present. In order to avoid this possibility, additional circuits to provide security were designed into the *Go out.* equipment. The term security will be defined for this purpose, as the prevention of the reproduction of a transmitted intelligence by conventional A.M. or F.M. receivers.

DISCUSSION

Experiments conducted with a pulse time modulated system indicated the following results. For proper reception, the signal to noise ratio of the input signal as measured at the detector output, was as follows: The PTM receiver, 2:1; The F.M.

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receiver, 8:1; And the A.M. receiver, 18:1.

Theoretically, various methods may be employed to provide security under these conditions of detection. The method that was chosen, and described in this report, is a means of masking the intelligence in a background of noise. Masking may be defined as the number of decibels by which a listeners threshold of audibility for a given tone is raised by the presence of another sound.

All communications systems normally include some noise, and invariably it is an undesirable feature. In general both the masked sound and the masking sound have highly complex wave forms and frequency structures.

Two books used as reference for this phase of the work are "Fundamentals of Acoustics" by L. E. Kinsler and A.R. Frey, and "Acoustic Measurements" by L. L. Beranek. They both describe masking experiments using pure sinusoidal tones. In performing experiments of this type, the masking tone is operated steadily

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at some particular intensity level, and the intensity of the signal tone is raised from a level below audibility to one that is just distinguishable.

The masking of one pure tone by another is most apparent when the two tones are of approximately the same frequency. In general a tone masks signals of higher frequency more effectively than it does those of lower frequency. As an example of relative masking effects, a signal of 1000 cps. and an intensity level of 40 db is completely masked by a 400 cycle tone whose intensity level is 80 db, but it is well above the threshold of audibility in the presence of a 2000 cycle tone of the same intensity.

This is readily explained by a consideration of the aural harmonics generated by the masking tones. For the 400 cycle, 80 db tone these harmonics have frequencies of 800, 1200, 1600, etc. cps. and have loudness approaching that of the fundamental, so that, since one or another of these harmonics will be approximately the same frequency as any signal in the upper audible range,

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it will provide effective masking. On the other hand, all the aural harmonics of the 2000 cycle tone have frequencies of 4000 cps. or more and do not mask the 1000 cycle signal.

The band of speech frequencies most important for intelligibility is that extending from about 1000 to 2500 cps. However, in the interests of making speech sound more natural, such as distinguishing male from female voices, it is usual to extend the band from 250 to 2750 cps.

From the above considerations it should be expected that a pure tone would be most effective in masking speech when its frequency was about 500 cps., for its more intense harmonics would be spread across the frequency band required for good articulation. Similarly it may be concluded that distorted waves such as square waves or series of pulses would be more effective in masking speech than are pure tones, for such masking signals are themselves rich in harmonic frequencies. The technical literature quoted previously bear this out.

When a pure tone is sounded in the presence of a random noise only the noise in a narrow frequency band on either side

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derives to mask it. A quantity known as the "recognition differential" (RD) is sometimes used as a measure of the conditions under which a signal is recognizable in the presence of a noise background. The RD is defined as the difference, expressed in decibels, between the signal and background intensity levels, when the signal can be recognized just 50 percent of the time.

Under certain conditions of signal bandwidth, noise background bandwidth, spectrum level of noise at signal frequency, and shape and frequency of the noise spectrum, the RD may be a negative value, meaning the signal may be smaller than noise. In general, for the same intensity of noise level, if the transmitted frequency range is narrowed, the RD is higher than if the entire speech and noise spectrum is transmitted.

The equipment as designed for the masking application, utilizes unlimited frequency range for both signal and noise at the modulator. However, the demodulation cuts off at 3000 cps. The design permits a signal to masking noise ratio of 1 to 2.

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DESIGN OF EQUIPMENT

There were two general circuits considered for this noise masking application. One would provide three distinct pulses; two of which would contain noise modulation and the third the signal. Because of the complexity of the transmitter circuitry, this design was temporarily shelved in favor of the second circuit.

In general, the system used has some distinct advantages over the three pulse system. It is essentially a two pulse system, which basically simplifies the circuitry. Furthermore it lends itself to a more efficient system in so far as duty cycle is concerned.

Possibly the greatest advantage pertains to this unique distinction. The three pulse system would have the lagging edge of each pulse as the deviating edge. It would be apparent to a monitor that the pulses contain some intelligence. By sampling each pulse in turn, the pulse carrying the signal could be demodulated and the intelligence derived. The two pulse unit, on the other hand, has no deviation on the first pulse, and causes both edges of the second pulse to deviate. The leading edge deviates with noise, and the lagging edge carries the signal. This condition would be more

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confusing to an observer. Sampling either pulse would not result in signal. The only means of deriving intelligence is to sample the lagging edge exclusively.

The modulator is indicated in Figure 1. The design incorporates a gas tube as a noise generator. The usual sporadic current flow of this type of tube is put through a plate resistor. The resulting noise voltages are coupled to additional noise amplifiers prior to performing noise modulation.

The basic controlling units are the saw tooth generators and multivibrators. A blocking oscillator acts as the basic frequency source, which provides a frequency of 6000 cycles per second. This pulse is fed to two parallel sections which comprise the signal and noise sections.

The noise section of the circuit eliminates the positive portion of the trigger pulse. By using the negative portion, a delay of 5 microseconds is obtained. This negative pulse is amplified and made positive, before triggering a saw tooth generator. The output of the saw tooth generator and the output of the noise amplifier are both coupled to a multivibrator. The output of

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the multivibrator is taken as a negative pulse. It is delayed fifteen microseconds and has its lagging edge deviating. The maximum deviation attained is ten microseconds.

The signal section is essentially unchanged from the original one channel circuit as described in the previous report. The blocking oscillator triggers a saw tooth generator. This is coupled to a multivibrator along with the modulating audio signal. The output of the multivibrator is taken off as a positive pulse that is 28 microseconds wide. The lagging edge deviates to correspond with the audio, and the maximum deviation is 5 microseconds. This results in a signal to noise which at the peak audio signals is no better than 1 to 2.

The outputs of the two multivibrators are combined and the noise pulse cancels the center section of the signal pulse. This results in two distinct pulses. The first pulse has neither edge deviating. The second pulse has both edges deviating; the leading edge is the noise factor and the lagging edge contains the signal.

The demodulator, for purposes of this test, was designed to accept the input as an ordinary audio amplifier, or to provide the special

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demodulation necessary to separate the signal from the noise. This was accomplished by switching the input either directly to the audio amplifiers or to the noise demodulator.

The circuit is represented by Figure 2. The double pulse P.D.M. input is fed to two parallel sections. The noise demodulator section consists of two pulse amplifiers, the output of which is differentiated. This replaces the original two pulses with a series of sharp pulses that trigger a multivibrator. The differentiator was necessary because the multivibrator had a tendency to follow the shape of the relatively wide pulses.

The output of the multivibrator is taken out as a positive pulse. The stage is designed to provide a pulse that is wide enough to cover the first pulse and part of the second pulse. At this point the positive multivibrator pulse is mixed with the original pulses which have a negative polarity due to one stage of amplification. The multivibrator pulse cancels out the first pulse and the leading or noise edge of the second pulse. This leaves the second pulse with

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a new and fixed leading edge, but with the lagging or signal edge unaffected. The new pulse is further amplified and then switched to a cathode follower. This in turn feeds the signal to a series of low pass filters and audio amplifiers, terminating in a loud speaker.

The parallel path consists of a pulse amplifier that handles both pulses, and then immediately switches them to the cathode follower.

TESTING

The system was tested on a closed wire basis. One test involved the use of the noise demodulator. The output was a noise free signal, with reasonable fidelity.

The second test was made with both the noise and signal coupled to the audio section. The result was complete masking of the signal by the noise. In addition to the absence of intelligibility, and of even greater importance, there was no apparent indication of the presence of speech. It sounded as though it was industrial noise.

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The waveforms at various positions were recorded and the test points are indicated on Figure 3 and 4. The oscillograms are shown as follows:

Fig. 5 The plate of the blocking oscillator shows a negative pulse.

Fig. 6 The output of the blocking oscillator used as the trigger pulse. It has a cycle duration of 160 microseconds or a frequency of 6000 cps.

Fig. 7 The input to the noise modulated channel, the positive half of the trigger pulse has been eliminated. This results in a delay of 5 microseconds.

Fig. 8 The pulse used to trigger the noise channel saw tooth generator, one stage of amplification has converted it to a positive pulse required for triggering.

Fig. 9 The output of saw tooth generator.

Fig. 10 The input to the multivibrator, the saw tooth generator output is reshaped by rectification to

SECRET

provide the conventional saw tooth wave form. The pulse now has a total delay with respect to the blocking oscillator of 15 microseconds.

Fig. 11 The plate of the gas tube noise generator; it is evidently white noise.

Fig. 12 The output of the noise amplification indicates an amplifier gain of 18 db.

Fig. 13 The output of the noise channel multivibrator; this is taken off as a negative pulse. The lagging edge is noise modulated. The leading edge has been delayed 15 microseconds.

Fig. 14 The output of the signal channel saw tooth generator.

Fig. 15 The input to the signal channel multivibrator, the wave has been reshaped to the conventional saw tooth shape and has the proper positive polarity. The pulse is delayed only 3 microseconds.

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Fig. 16 The input to the audio amplifier; it is a 1000 cps. tone.

Fig. 17 The output of the last audio amplifier; the saw tooth trigger pulse is superimposed.

Fig. 18 The output of the signal channel multivibrator; it is taken out as a positive pulse with the lagging edge signal modulated. The pulse is 28 micro-seconds wide.

Fig. 19 The two multivibrator outputs have been combined. The noise pulse has cancelled out the center section of the signal pulse. The first pulse of the two has no moving edges since they both represent the stationary leading edges of the original pulses. The second pulse has both edges deviating. The leading edge is noise modulated, and the lagging edge is signal modulated.

The following oscillograms were taken at the demodulated section.

The test points are indicated on Fig. 4.

Fig. 20 The combined pulses after two stages of amplification.

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Fig. 21 The input to the multivibrator; this has been differentiated to insure more positive triggering action. It was found that the original pulses tended to cause double triggering, which effect was eliminated by using the sharp differentiated pulses.

Fig. 22 The output of the multivibrator, taken out as a positive pulse. It is about 20 microseconds wide, and wide enough to cover the first pulse and the leading noise edge of the second pulse.

Fig. 23 The original pulses after one stage of amplification. They are now of negative polarity which is required for cancellation.

Fig. 24 The input to the mixer, the multivibrator pulse has cancelled out the first pulse and part of the second. The leading edge is now fixed and the lagging edge is signal modulated.

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Fig. 25 The output of the mixer, indicates further amplification to bring the level up to the required value before switching to the audio and filtering sections.

Fig. 26 The input to the cathode follower indicates an additional gain of 16 db.

Fig. 27 The output of the first low pass filter, the 6000 cps. ripple is about 20 per cent of the signal.

Fig. 28 The output of the second low pass filter indicates a ripple of about 8%.

Fig. 29 The secondary of the output transformer indicates a reasonably smooth sine curve and shows the overall fidelity of the system.

CONCLUSION AND FUTURE PLANS

A pulse duration modulated system was designed to incorporate security against conventional detectors, irrespective of the signal strength at the receiver.

This was designed on a basis of masking the signal in a background of white noise.

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The modulator and demodulator were tested and it was found that with the use of a signal to masking noise ratio of 1 to 2 there was no intelligibility. In addition, there was no indication of the presence of signal in the noise. The demodulator gave every indication of atmospheric and/or industrial noise, with no audible sign of signal.

It is planned to test the transmitter and receiver for operating range and system efficiency.



FIG.1



FIG. 2

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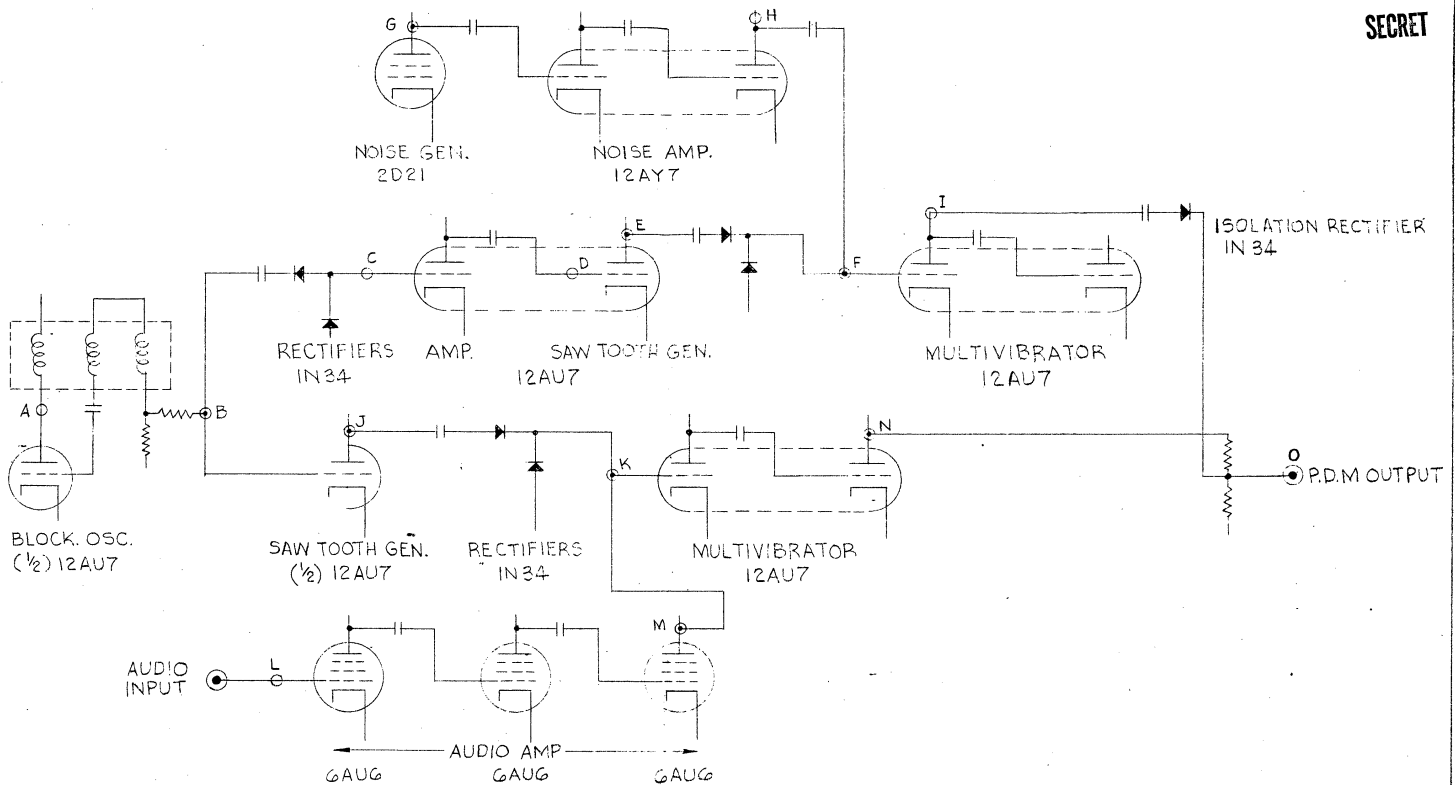
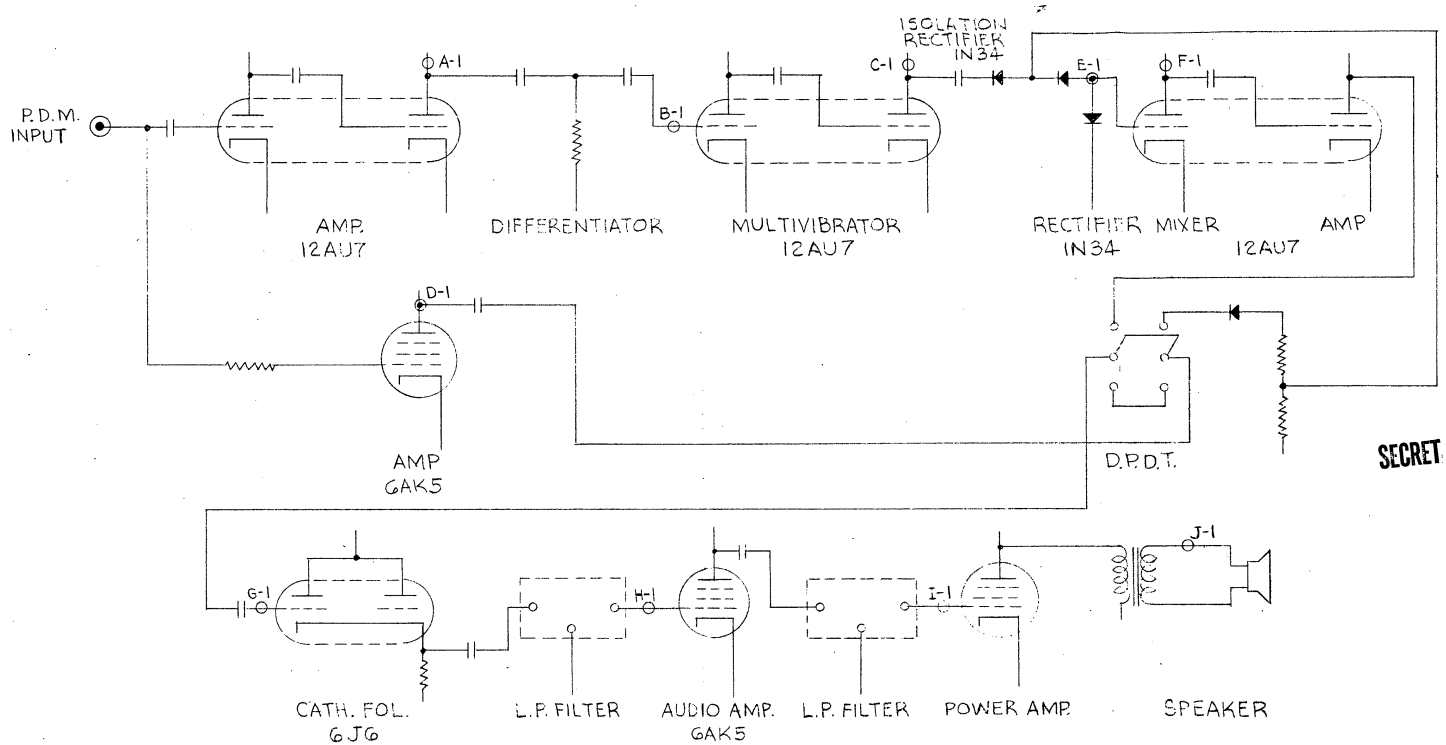


FIG. 3 - OUTLINE OF P.D.M. MODULATOR - NOISE MASKING

FIG. 3

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FIG. 4 - OUTLINE OF P.D.M. DEMODULATOR-NOISE MASKING

FIG. 4

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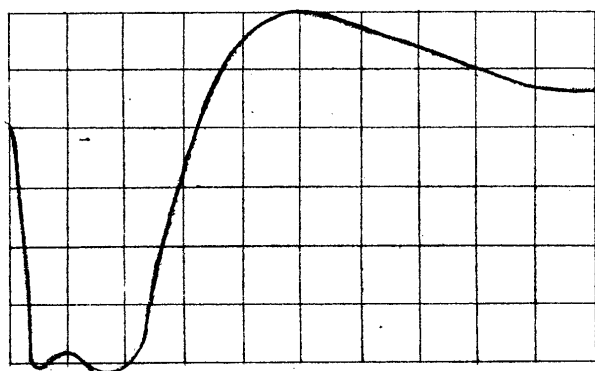


FIG. 5

SENSITIVITY-V/CM 43
SWEEP- μ SEC/CM 1
SIGNAL A

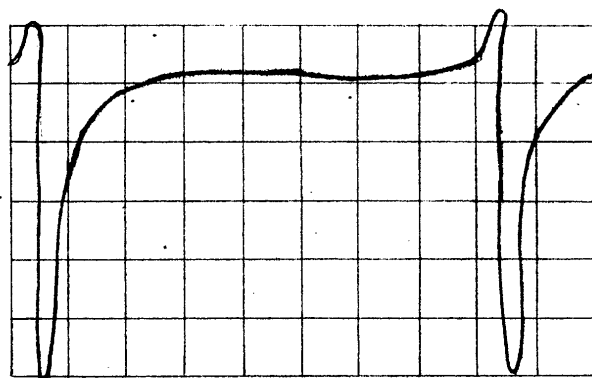


FIG. 6

SENSITIVITY-V/CM 8
SWEEP- μ SEC/CM 20
SIGNAL B

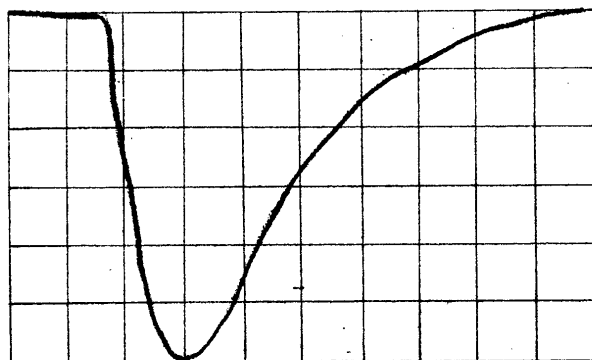


FIG. 7

SENSITIVITY-V/CM 4
SWEEP- μ SEC/CM 2.4
SIGNAL C

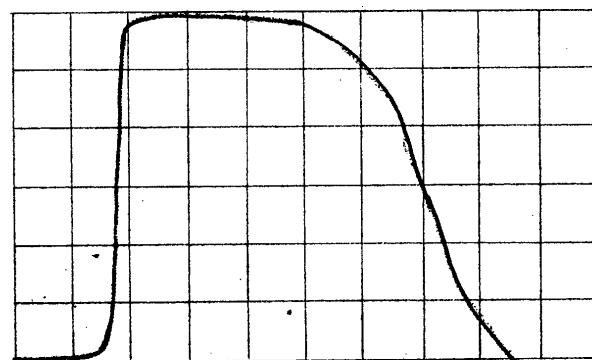


FIG. 8

SENSITIVITY-V/CM 8
SWEEP- μ SEC/CM 2.4
SIGNAL D

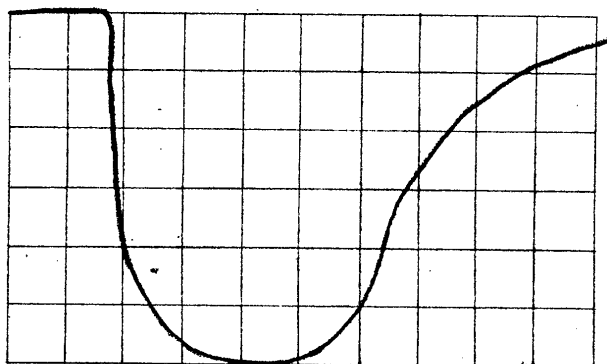


FIG. 9

SENSITIVITY-V/CM 35
SWEEP- μ SEC/CM 2.4
SIGNAL E

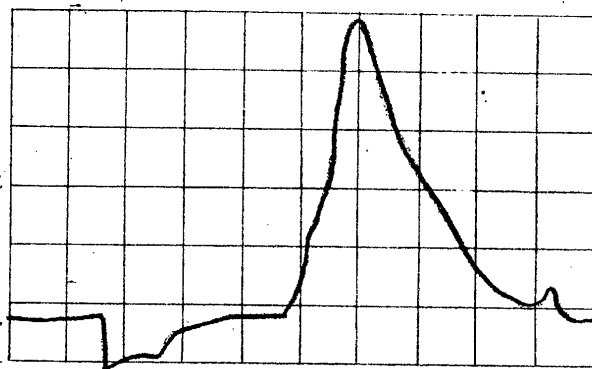


FIG. 10

SENSITIVITY-V/CM 7
SWEEP- μ SEC/CM 2.7
SIGNAL F

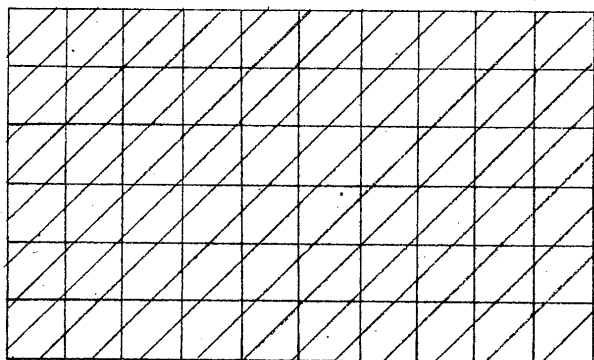


FIG. 11

SENSITIVITY-V/CM 2
SWEEP- μ SEC/CM 100
SIGNAL G

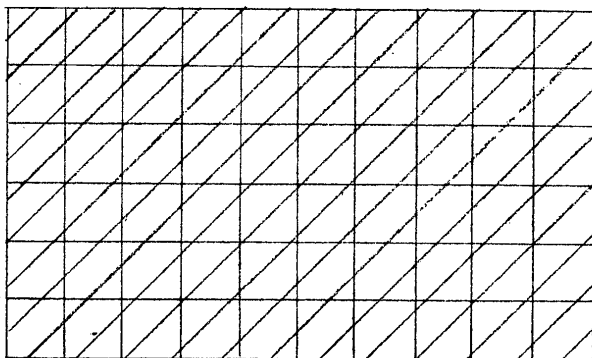


FIG. 12

SENSITIVITY-V/CM 16
SWEEP- μ SEC/CM 100
SIGNAL H

Page 22

SECRET

SECRET

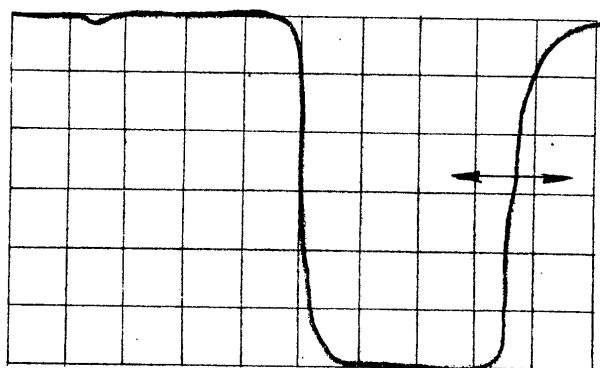


FIG. 13

SENSITIVITY-V/CM 17
SWEEP- μ SEC/CM 3
SIGNAL I

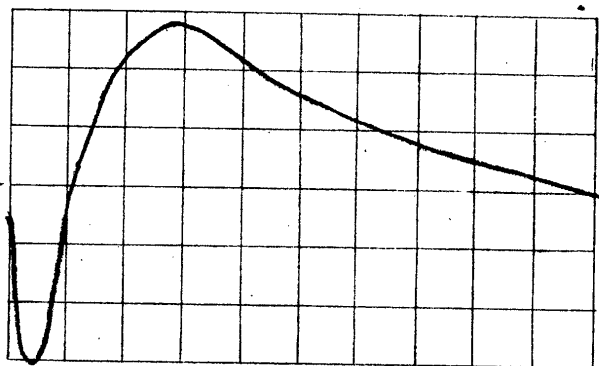


FIG. 14

SENSITIVITY - V/CM 30
SWEEP- μ SEC/CM 4.0
SIGNAL J



FIG. 15

SENSITIVITY-V/CM 5
SWEEP- μ SEC/CM 1.4
SIGNAL K

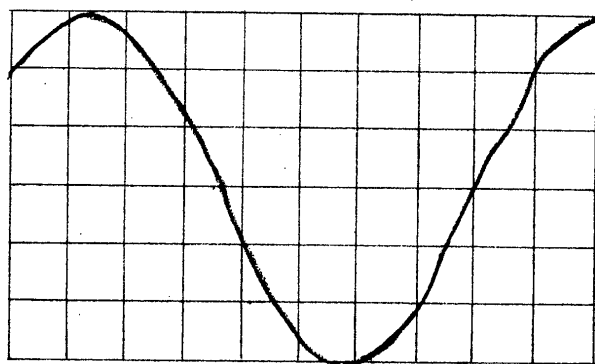


FIG. 16

SENSITIVITY-V/CM 0.3
SWEEP- μ SEC/CM 110
SIGNAL L

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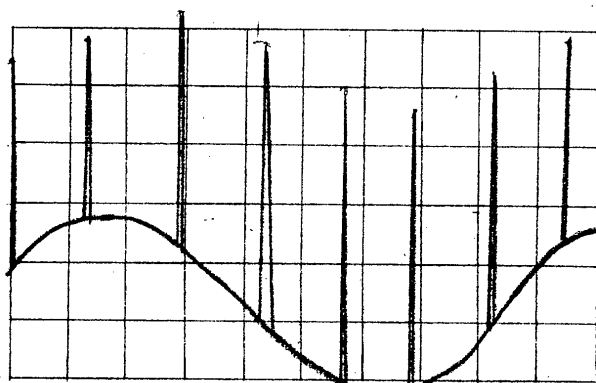


FIG. 17

SENSITIVITY-V/CM 8
SWEEP- μ SEC/CM 120
SIGNAL M

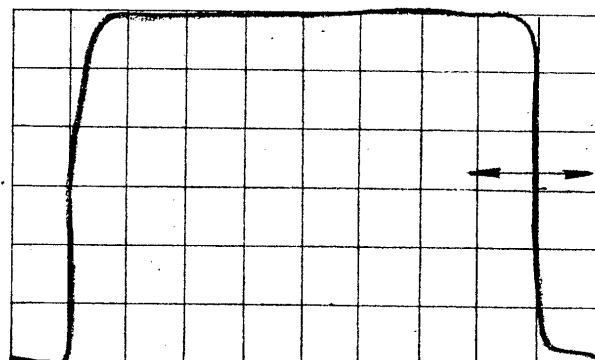


FIG. 18

SENSITIVITY - V/CM 12
SWEEP- μ SEC/CM 3.5
SIGNAL N

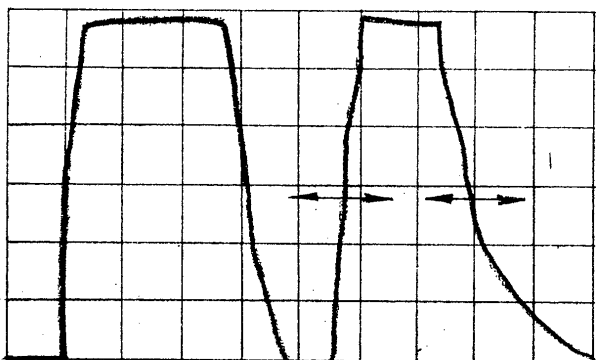
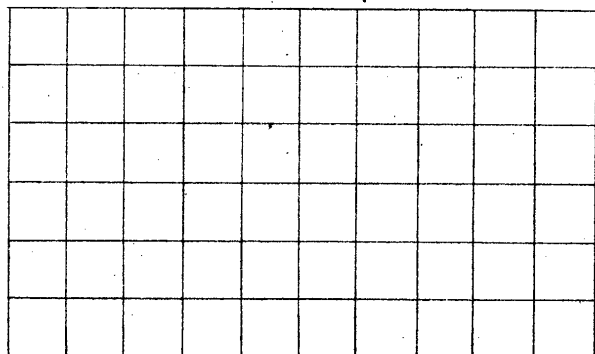


FIG. 19

SENSITIVITY-V/CM 1
SWEEP- μ SEC/CM 4.2
SIGNAL O



SENSITIVITY-V/CM _____
SWEEP- μ SEC/CM _____
SIGNAL _____

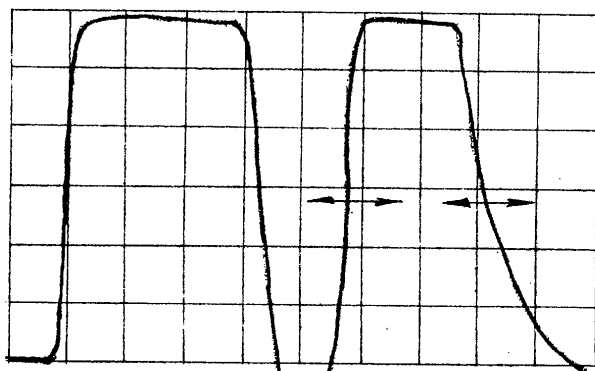


FIG.
20

SENSITIVITY-V/CM 18
SWEEP- μ SEC/CM 4.2
SIGNAL A-1

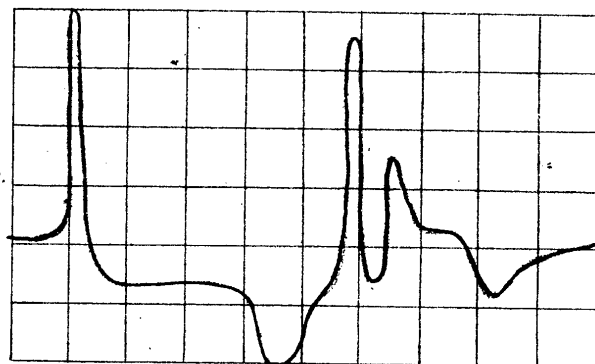


FIG.
21

SENSITIVITY-V/CM 2
SWEEP- μ SEC/CM 4.2
SIGNAL B-1

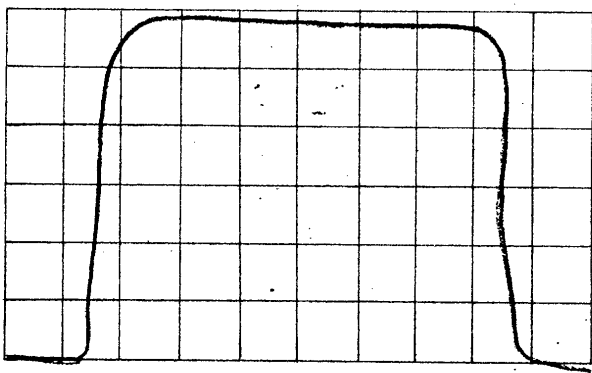


FIG.
22

SENSITIVITY-V/CM 10
SWEEP- μ SEC/CM 3.0
SIGNAL C-1

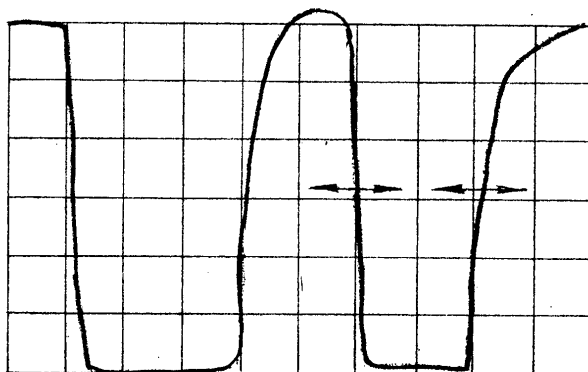


FIG.
23

SENSITIVITY-V/CM 23
SWEEP- μ SEC/CM 4.0
SIGNAL D-1

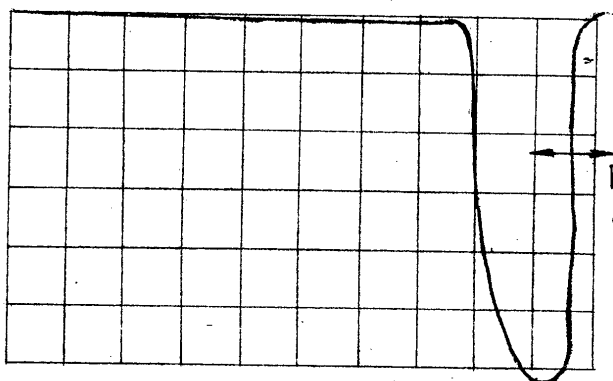


FIG.
24

SENSITIVITY-V/CM 1.6
SWEEP- μ SEC/CM 3.4
SIGNAL E-1

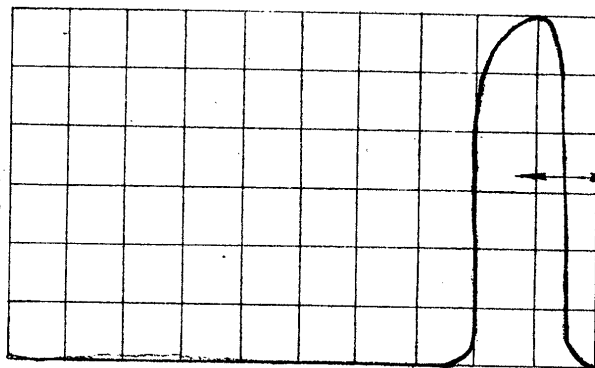


FIG.
25

SENSITIVITY-V/CM 4
SWEEP- μ SEC/CM 3.4
SIGNAL F-1

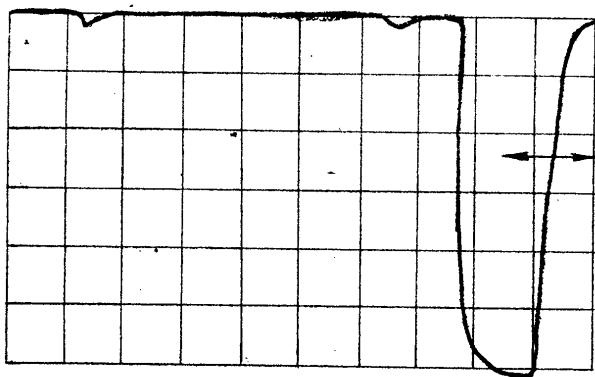


FIG.
26

SENSITIVITY-V/CM 16
SWEEP- μ SEC/CM 3.4
SIGNAL G-1

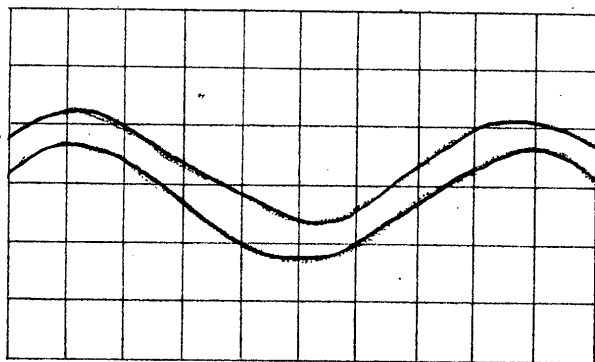


FIG.
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SENSITIVITY-V/CM .03
SWEEP- μ SEC/CM 130
SIGNAL H-1

Image 26

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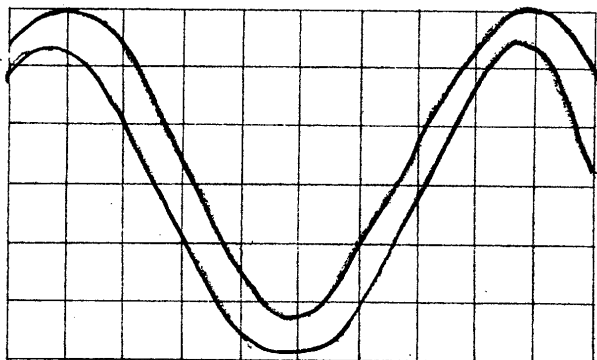
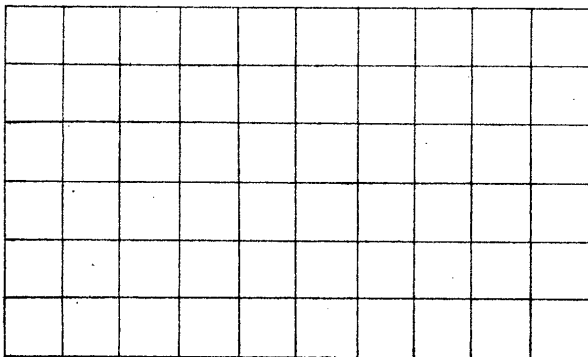


FIG.
28

SENSITIVITY-V/CM 0.13
SWEEP- μ SEC/CM 130
SIGNAL I-I



SENSITIVITY-V/CM _____
SWEEP- μ SEC/CM _____
SIGNAL _____

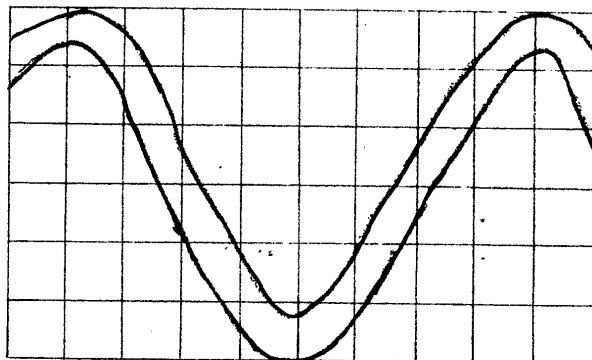
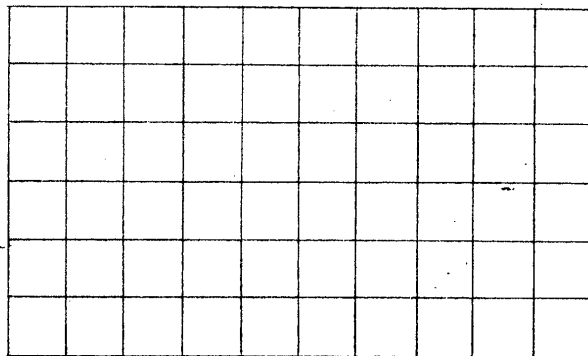


FIG.
29

SENSITIVITY-V/CM 0.04
SWEEP- μ SEC/CM 130
SIGNAL J-I



SENSITIVITY-V/CM _____
SWEEP- μ SEC/CM _____
SIGNAL _____

27

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